A Mirror Based Event Cloaking Device

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Abstract

We propose a way of implementing an event cloaking device without the use of metamaterials. Rather than slowing down and speeding up light, we manipulate an obscurity gap by diverting the light through paths of appropriate length with an arrangement of switchable transreflective mirrors.

1 Introduction

A spacetime cloak, or event cloak, is a means of manipulating electromagnetic radiation in space and time in such a way that a certain collection of happenings, or events, is concealed from distant observers. Conceptually, a safecracker can enter a scene, steal the cash and exit, whilst a surveillance camera records the safe door locked and undisturbed all the time.

An event cloak design using metamaterials was first proposed theoretically by a team of researchers from Imperial College London (UK) in 2010, and published in the Journal of Optics [1]. Their design works by using a medium in which different parts of the light illuminating a certain region can be either slowed down or speed up. A leading portion of the light is speeded up so that it arrives before the events occur, whilst a trailing part is slowed down and arrives too late. After their occurrence, the light is reformed by slowing down the leading part and speeding up the trailing part. The distant observer therefore only sees a continuous illumination, whilst the events that occurred during the dark period of the cloak's operation remain undetected. An experimental demonstration of the basic concept using nonlinear optical technology has been presented in a preprint on the Cornell physics arXiv [2].

Here we describe a similar event cloak device without metamaterials, using only a system of mirrors that create a temporary gap of obscurity, and close that gap afterward.

2 Description of the mirror-based event cloaking device.

Figure 1 shows the basic arrangement for a mirror-based event cloak device. It consists of a light source L, and a system of mirrors A, B, C, D, E, F, G, H, of which A, D, E and H are switchable between several possible states: fully transparent (letting light go through), fully reflective (working as an ordinary mirror), and adjustable degrees of half-reflection. Electrically switchable transreflective mirrors are currently available, so the device described here is within the scope of current technology.

The arrangement of the mirrors may change, for instance it is possible to make the paths ABCD and EFGH longer by inserting extra mirrors (and so obtain a larger time gap for the event cloaking effect), but the times taken by the light to go through each of those paths must be identical.

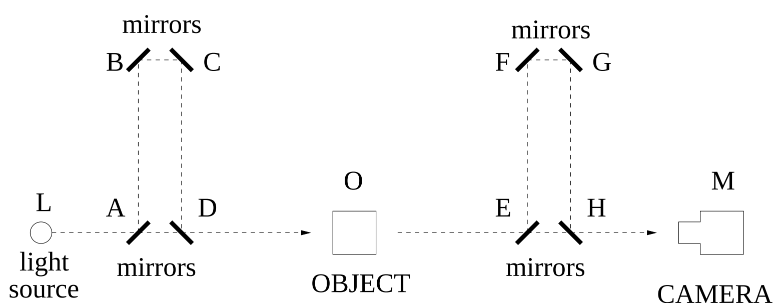

Figure 1: Basic design of mirror-based event cloak.

The light produced by the light source L illuminates the object O after following one of the two paths LADO, or LABCDO, depending on whether mirrors A and D are set in the transparent or the reflective state. Then, the light leaving the object will reach the camera M also after following one of two paths, OEHM, or OEFGHM, depending on the transparent or reflective state of mirrors E and H.

3 Performing event cloaking.

In order to accomplish the event cloak effect, switching of the four mirrors A, D, E, and H must be carefully timed, so to create a temporary gap of obscurity in the light arriving to the object, to be precisely closed in the light leaving the object and arriving to the camera.

The system is initially set as shown in figure 2, with mirrors A and D in their transparent state, and mirrors E and H in their reflective state.

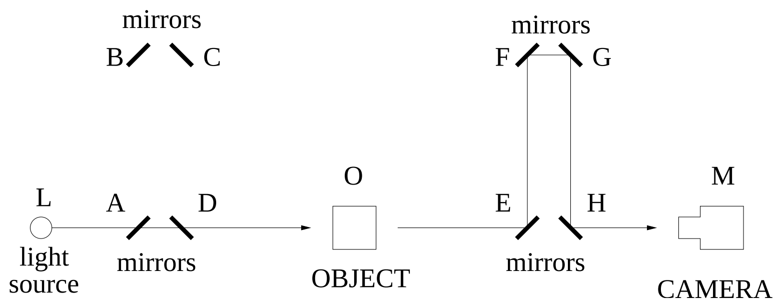

Figure 2: Initial setting: A and B are transparent, E and H are reflective.

The event cloaking effect starts as shown in figure 3, with mirror A switching to its reflective state, and after the light between A and D has gone through mirror D, this mirror switches to a reflective state too. This create an obscurity gap of duration equal to the time taken by the light to go through the path ABCD minus the time taken to go directly from A to D—in the figure AD=BC and AB=CD, so the duration of the gap would be twice the time taken by the light to go from A to B.

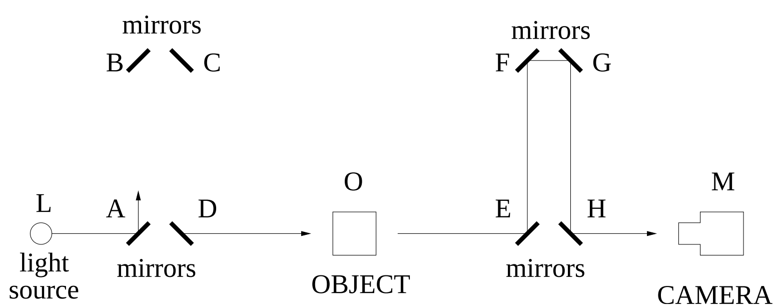

Figure 3: Starting the obscurity gap: A switches to a reflective state, a little later D switches to reflective too.

Figure 4 shows the object in total obscurity. Anything that happens at O during the time duration of the obscurity gap will be invisible for the camera.

Figure 5 shows the end of the obscurity gap. The object is being illuminated again and the closing of the gap starts by switching mirrors E and (a

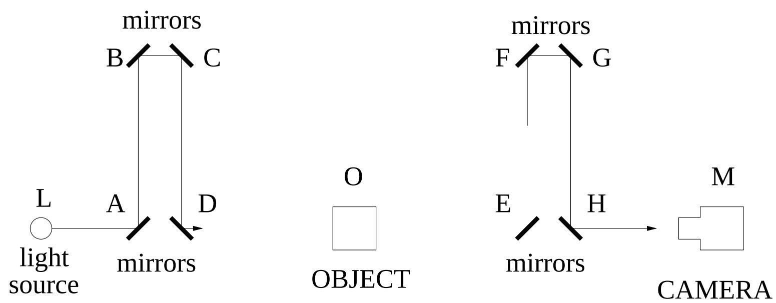

Figure 4: The object in the middle of the obscurity gap.

little later) H to transparent state.

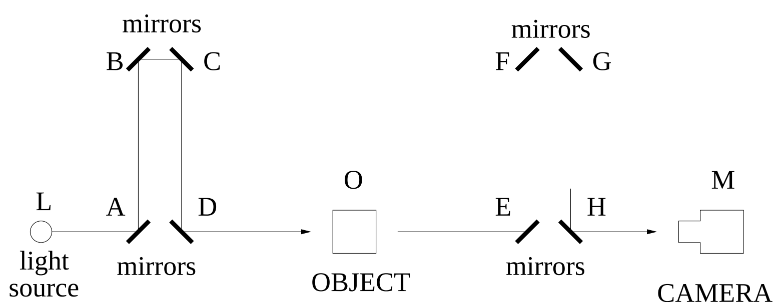

Figure 5: End of the obscurity gap. By now E has switched to transparent.

In figure 6 the obscurity gap has been closed, E and H are both transparent, event cloaking finished.

During all this time the camera has not registered any interruption in the reception of the image of the object, although nothing happening at O during the obscurity gap has been recorded by the camera. The only clue of the cloaking phenomenon would be a sudden jump in time in the image received by the camera. If for instance there is a clock at O showing 12:00 pm at the moment in which the obscurity gap reaches the object, and the gap lasts 5 minutes, then the image recorded by the camera would register a sudden jump from 12:00 pm to 12:05 pm.

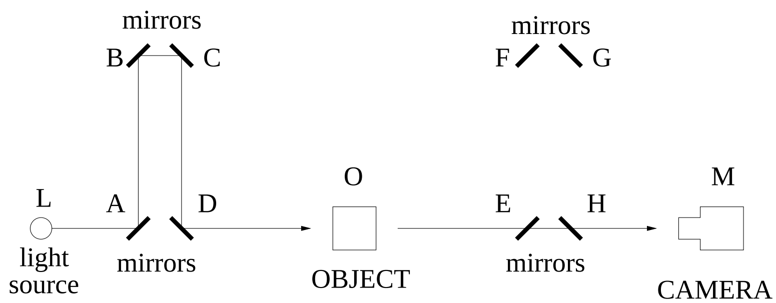

Figure 6: Obscurity gap closed, E and H are both transparent, event cloak finished.

4 Resetting the device.

If we want to use the device again we need to reset it to its original state shown in figure 2. In order to do so we time the transreflective mirrors A, D, E, and H to switch in the way described below.

First we switch mirror A to its transparent state, as shown in figure 7.

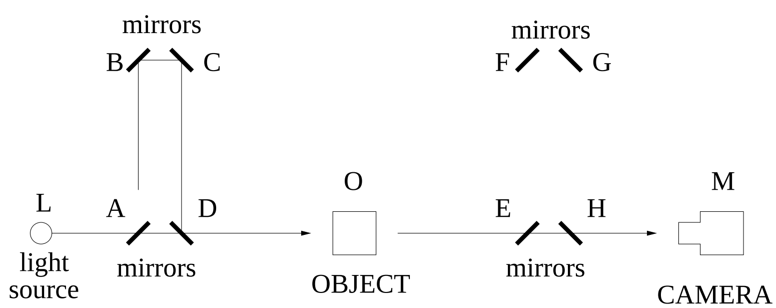

Figure 7: Reset starts: A switches to transparent.

Then, for a time equal to the previous duration of the obscurity gap, light going through the path AD will arrive at D at the same time as light that took the path ABCD. Combining the two beams into one may have different effects depending on the kind of light used. With ordinary light we may obtain a light beam with roughly the sum of the intensities of the incident beams, but other kinds of light (such as laser) may cause interferences. Here we leave open the precise way to combine the incident beams and its consequences, and will assume for now that they produce a (double intensity) combined beam leaving D towards O, as shown in figure 8.

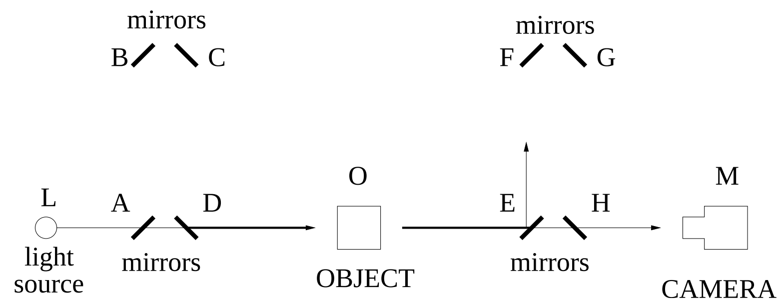

Figure 8: Beams combined at D illuminate the object. Mirror E working as a splitter.

As soon as the light in the path ABCD has exited, mirror D can be switched to a fully transparent state. Also, during the time the combined beam is arriving at E, this mirror must work as a splitter, producing two beams, one going directly from E to H, and another one following the path EFGH (figure 8).

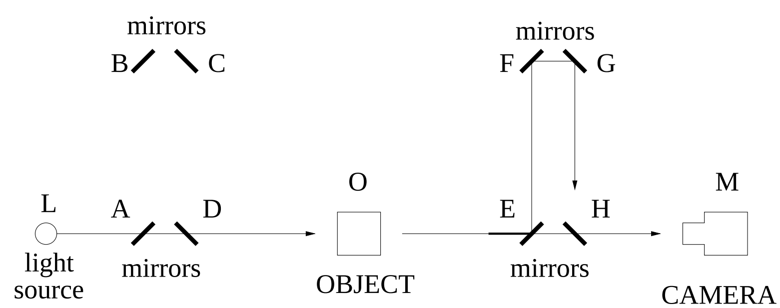

Figure 9: Reset finishing. Mirror E switches to fully reflective, and a little later H does the same.

Figure 10 shows the end of the reset process. Note that the light arriving at E has been split into two beams that will arrive at M at different times, so the camera will witness the object O going through the same period of time twice. If there is for instance a clock showing 12:30 pm at the moment the combined beam created at D arrives at O, and that bean illuminates the object for 5 minutes (same as the obscurity gap before), then the camera will record the clock going from 12:30 pm to 12:35 pm, then jumping back to 12:30 pm, and working normally from then on.

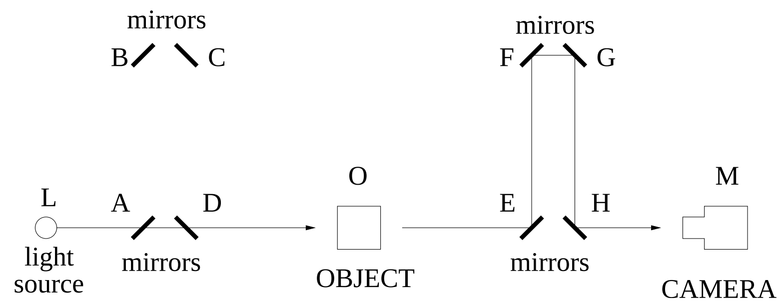

Figure 10: Reset done.

5 Conclusions

We have shown how to create an event cloak device without the use of metamaterials, by a simple arrangement of switchable transreflective mirrors. In the light arriving to an object an obscurity gap is created by diverting the incoming light through a longer path, and this gap is closed in the light path leaving the object by deviating the light through a shorter path.

References

[1] M. W. McCall, A. Favaro, P. Kinsler, and A. Boardman. A spacetime cloak, or a history editor. *Journal of Optics*, 13(2):024003, February 2011.

[2] Yoshitomo Okawachi Alexander L. Gaeta Moti Fridman, Alessandro Farsi. Demonstration of temporal cloaking. arXiv:1107.2062v1 [physics.optics].